Improved Thermal Spray Consistency Via Plume Sensors: An Aerospace Perspective

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TSS Aerospace Coatings Symposium

Outline

Plume Diagnostics

- Sprayview System with Abradables
  - Analysis of the powder injector site with the Sprayview System
  - Determine the best injection site and combination of powder and carrier gas
- The Plume Sensor can measure HVOF and any other conventional thermal spray process for
  - The balance of thermal energy (temperature)
  - Intensity (powder feed and thermal mass)
  - Speed (velocity)
- The Plume Sensor data can assist in meeting stringent aerospace specifications
  - Can be relied upon in conjunction and correlation with
    - Microstructural
    - Tensile
    - Hardness

Plume Sensor Technology

- Real time data
- Don’t wait for the lab
- Instant feedback
- Can we use this to replace metallography and testing which is an absolute requirement for aerospace work??

You can decide!!

Unlock that frozen process!!!

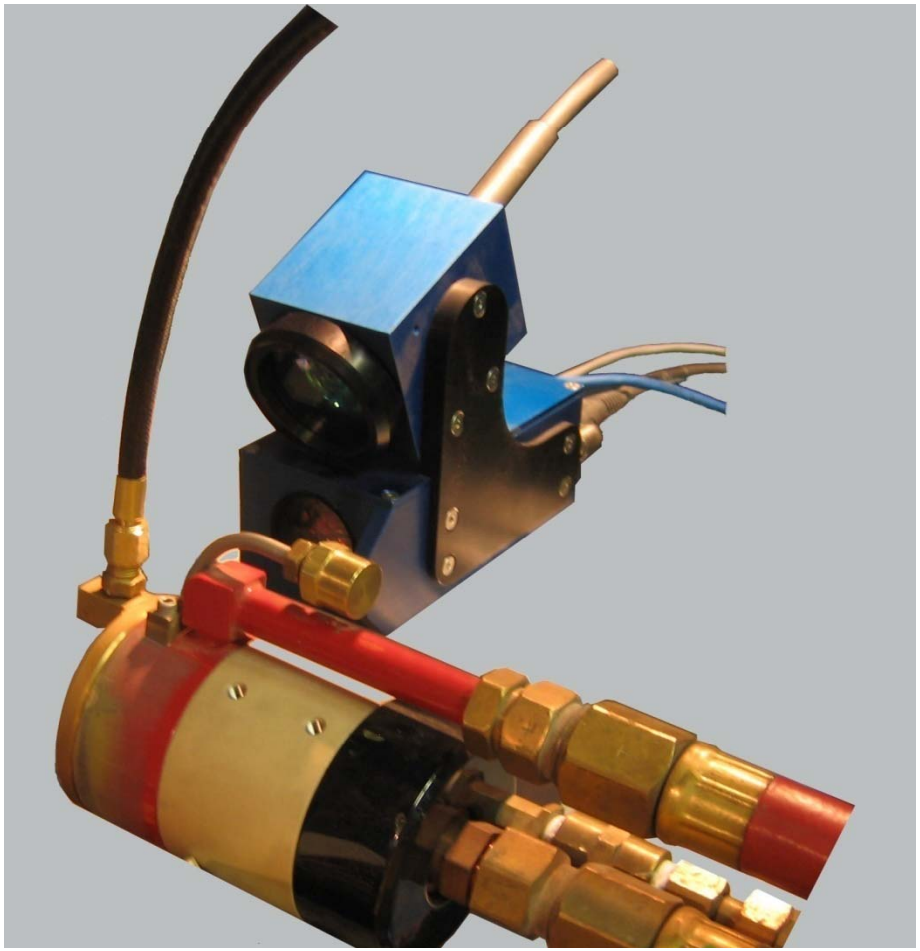
SprayView:
The Objectives of the Work

- To be able to visualize the injected thermal spray particles WITHIN the plasma itself
- To be able to measure the injection cone WIDTH & ANGLE
- To be able to measure particle VELOCITY, ACCELERATION & TRAJECTORY/ANGLE
- To be able to save LIVE VIDEO & replay those videos for post-process analysis
- Eventually to allow better characterization of coatings like abradables (blend or “co-injection”)

TECNAR AUTOMATION LTÉE

Sauer Engineering

The Instrument: Sensor Head &Setup



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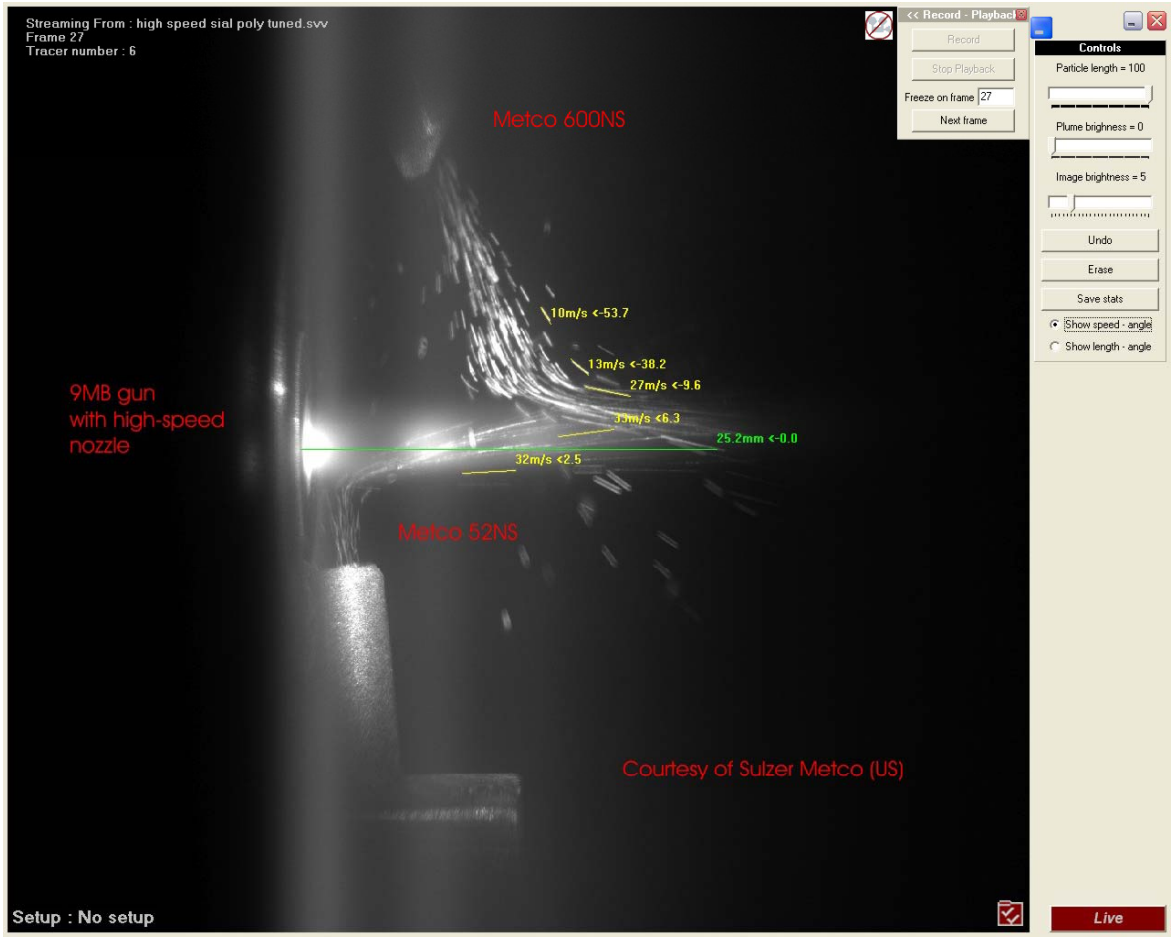
Co-injection



Plume Sensor Technology

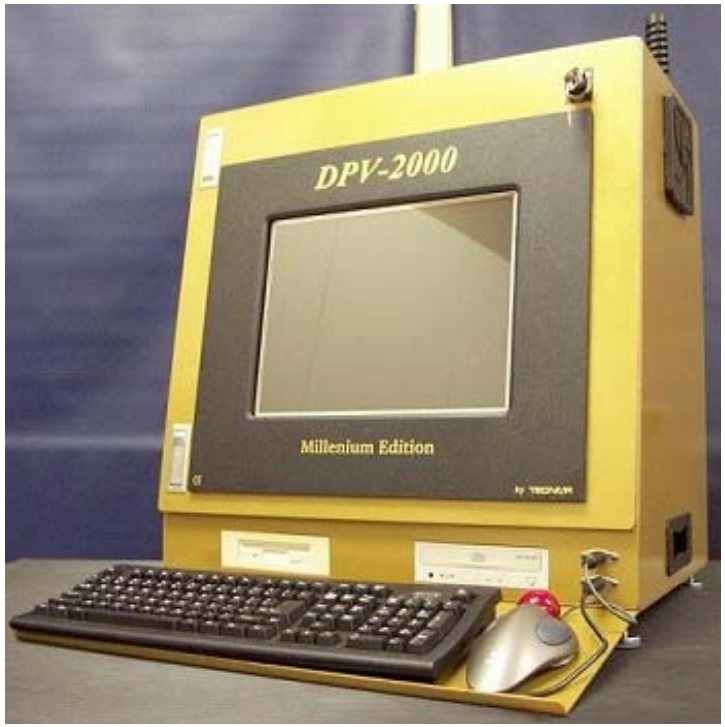
- Many advances over the last 10 years
- Hundreds of units all over the world
- More acceptance by OEM's

Plume Sensor Technology

- DPV 2000
  - Research
  - Individual particles
- Accuraspray
  - Production
  - Average values

DPV-2000 In-Flight Particle Sensor

- The ONLY instrument worldwide that can characterize INDIVIDUAL particles
- Temperature, Velocity, Diameter & Flux
- Fully automated cross-sectional mapping of the spray plume
- Widely accepted as the defacto standard instrument for process understanding, development & modeling



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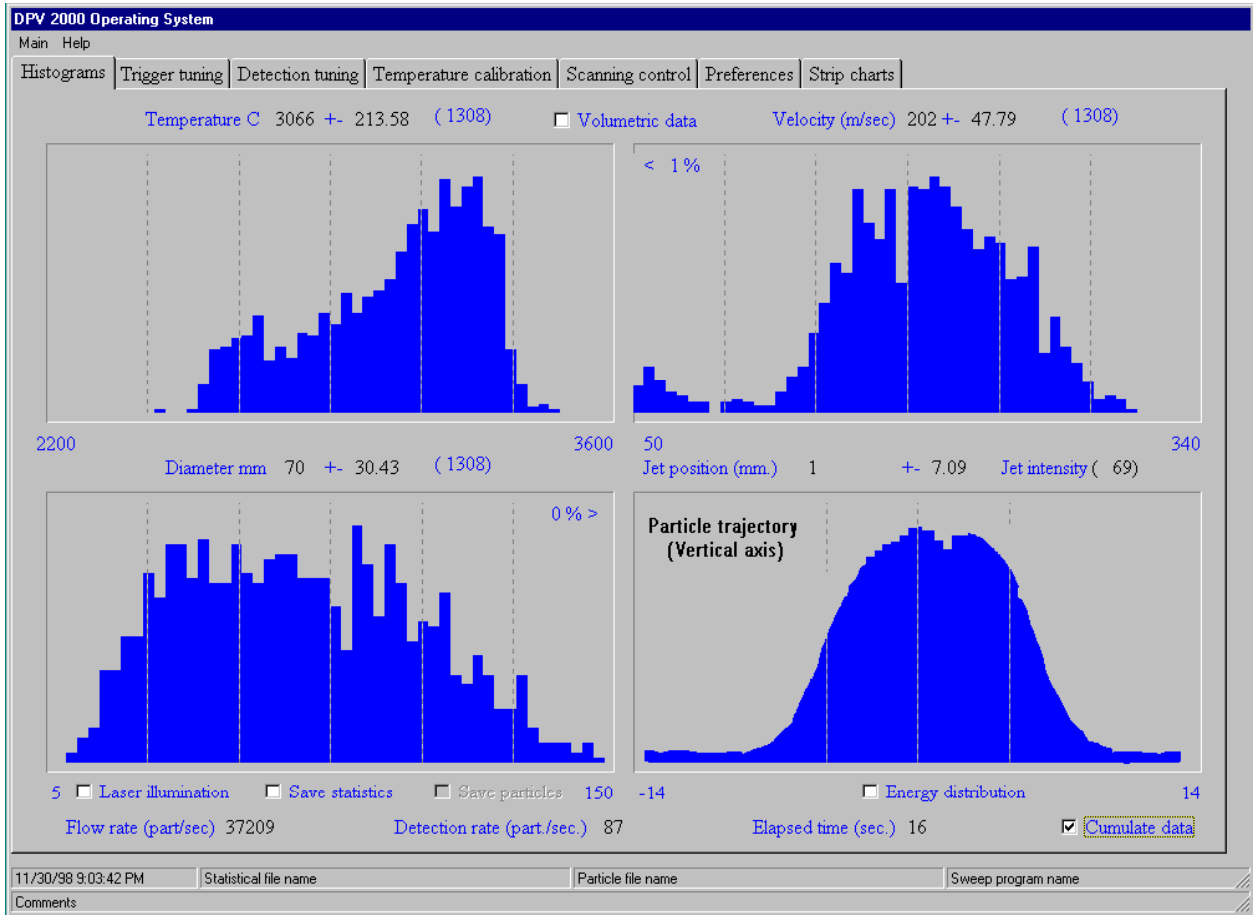
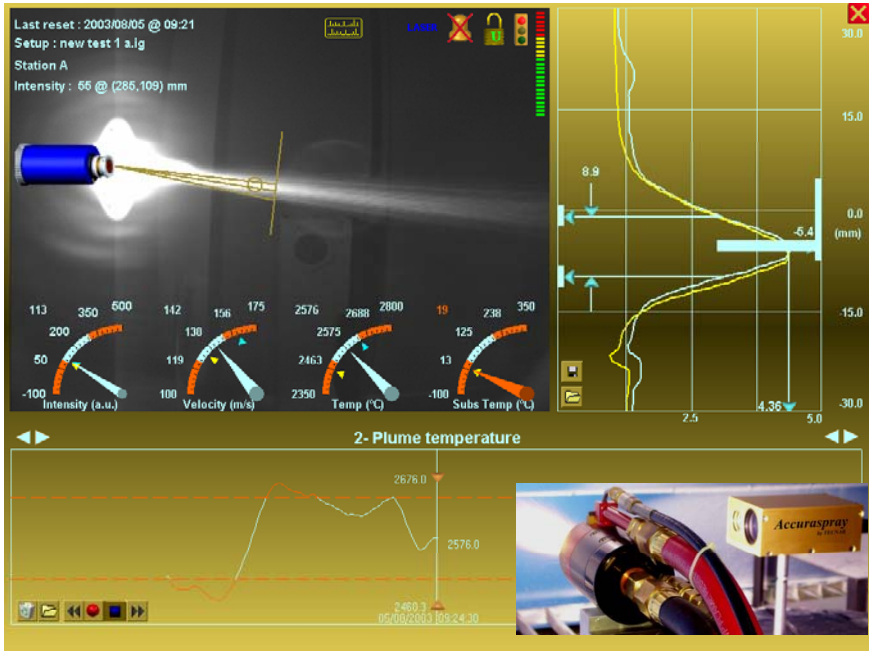
DPV-2000


DPV 2000 Operating System
Main Help
Histograms
Trigger tuning
Detection tuning
Temperature calibration
Scanning control
Preferences
Strip charts
Temperature C 3066 +- 213.58 (1308)
Volumetric data
Velocity (m/sec) 202 +- 47.79 (1308)
< 1 %
2200
3600
50
340
Diameter mm 70 +- 30.43 (1308)
Jet position (mm.) 1 +- 7.09 Jet intensity (69)
0 % >
Particle trajectory
(Vertical axis)
5
Laser illumination
Save statistics
Save particles
150
-14
Energy distribution
14
Flow rate (part/sec) 37209
Detection rate (part./sec.) 87
Elapsed time (sec.) 16
Cumulate data
11/30/98 9:03:42 PM
Statistical file name
Particle file name
Sweep program name
Comments

Accuraspray Usage

- Plume sensors are becoming a very useful tool in the TS industry
- These sensors measure many parameters as mentioned earlier
  - Temperature
  - Velocity
  - Intensity
  - Plume location and geometry

Accuraspray-G3



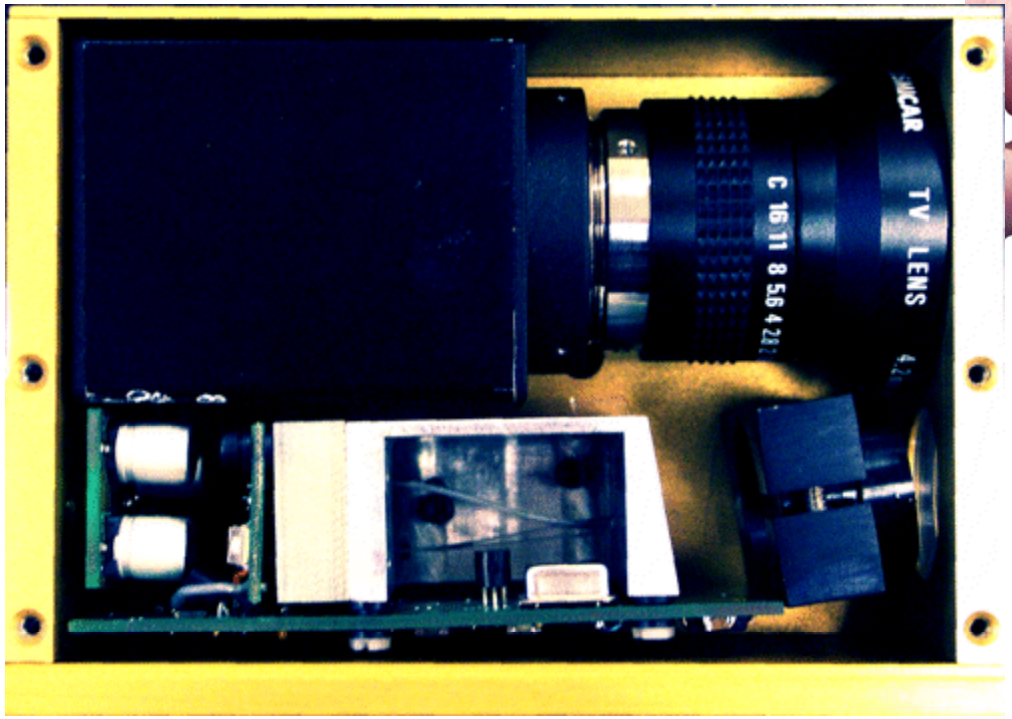
- Typical Accuraspray control screen
- Simultaneous measurement of bulk average T & V
- Simultaneous measurement of spray plume WIDTH, POSITION & INTENSITY
- Optional substrate temperature pyrometer

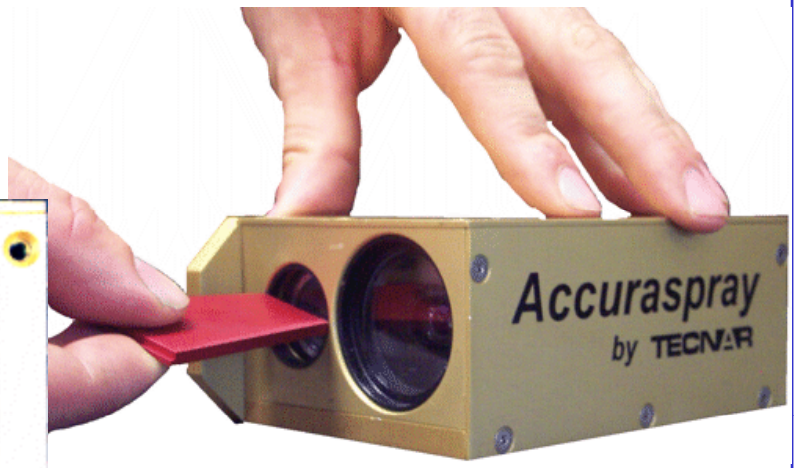
Can be configured as a TWIN unit, meaning that a single controller can handle 2 sensors heads looking simultaneously at two different processes

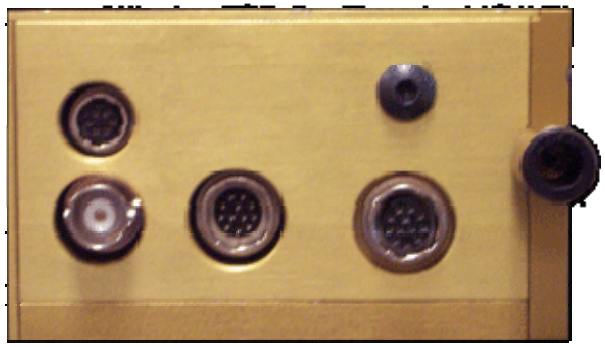
New G3C

- New capabilities/features
  - Same measurements but all-ethernet communication
  - Experiment file video
    - Use to illustrate abnormal conditions
      - Water leak in HVOF??
      - Inconsistent powder feed rate
      - Troubleshooting videos
  - Data is digitized in head
  - Recording system has more capability
  - Can now put program on individual computers and read stripcharts and videos

Fundamentals: Inside the Sensor Head







Low emission and high emission heads

or

HVOF and Plasma heads

TECNAR AUTOMATION LTÉE

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Accuraspray Usage

- Distance from head to sensor
  - 8” because Tecnar said so – like focus for camera
- Spray distance
  - What does the tech sheet say?
- 10 minute set-up
  - 5 minutes to boot Windows XP

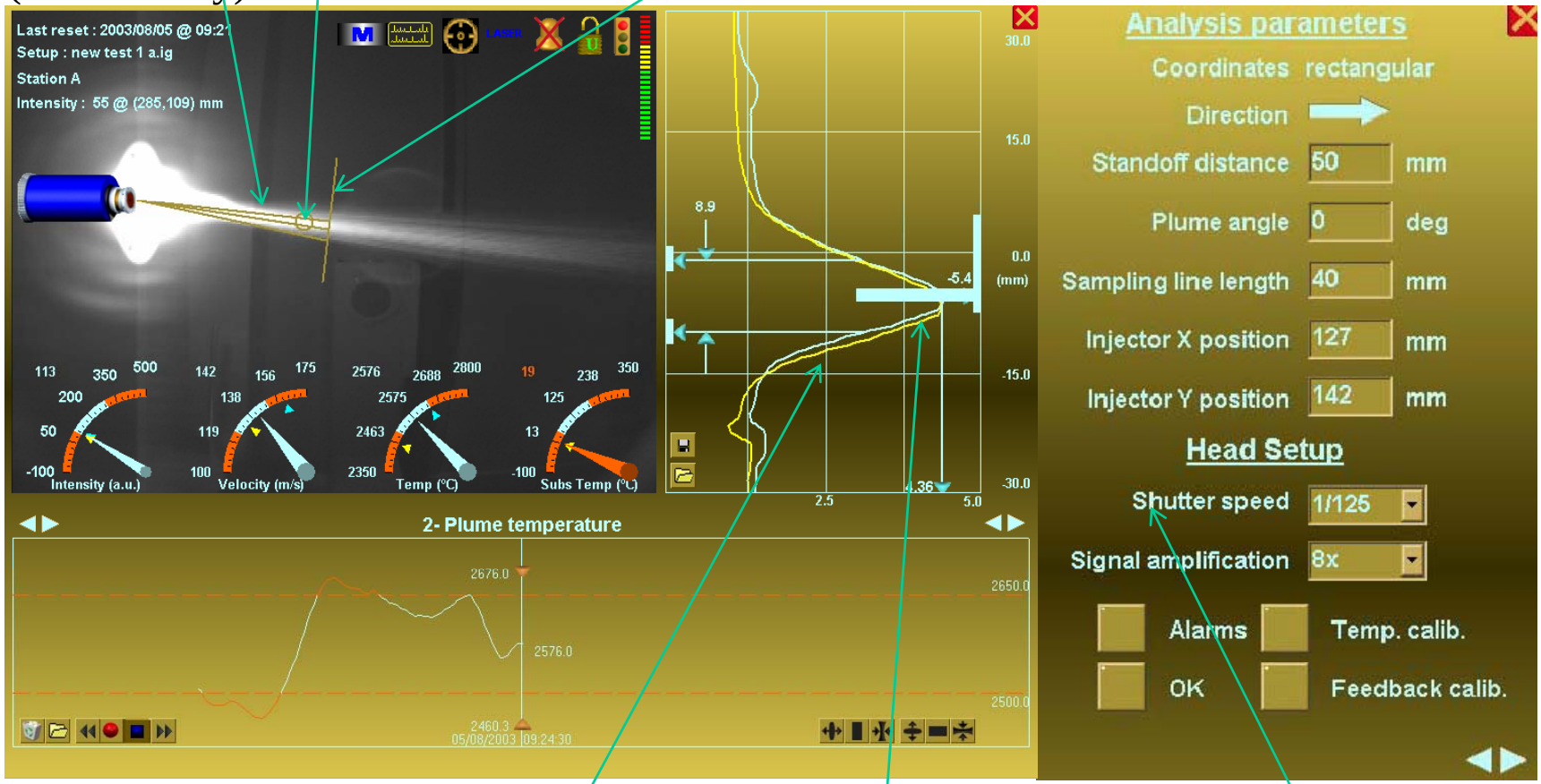
Accuraspray Usage

- Plume diagnostics with camera
  - Outputs will be
    - Plume width
    - Plume height
    - Plume location and angle
  - What do I set
    - *Sampling line* (regulates plume width)
    - *Plume angle* (sets angle in picture perpendicular to real plume)
    - *Shutter speed* (to keep plume shape on screen and not saturated)
    - *Gun position* (try to center plume on the screen with location for monitoring-this will be home position for monitoring and hopefully repeatable from measurement to measurement)

Angle
(see visually)

Stand-off

Sampling line (volume you are measuring)



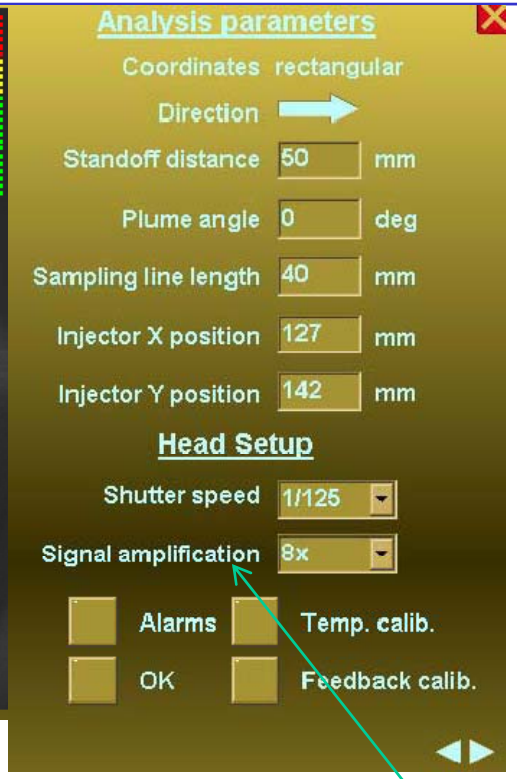
Plume width and location

Intensity
(area under curve)

Shutter speed
(how bright will it be)

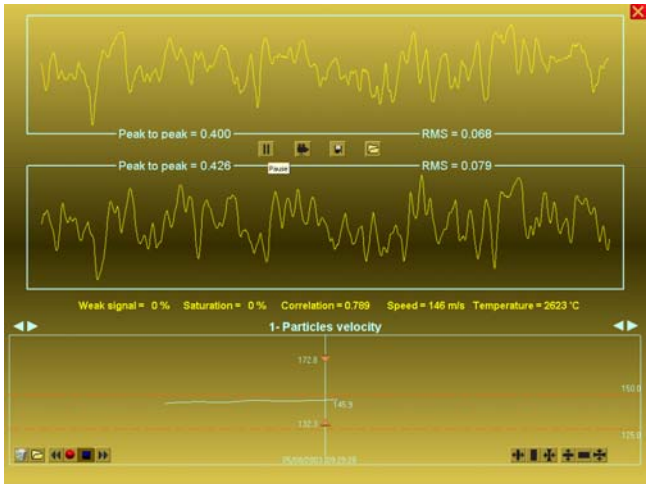
Accuraspray Usage

- Velocity and temperature with sensors
  - Outputs will be
    - Temperature
    - Velocity (critical that sensor is 90^{o} to spray plume)
- What do I set
    - *Gun position* (try to center plume on the screen with location for monitoring-this will be home position for monitoring and hopefully repeatable from measurement to measurement)
    - Signal amplification
      - Start at 128x and work down if needed
      - Decrease saturation to acceptable level and increase correlation



Velocity

Temperature



Amplification
(amplify the signal)

Raw Signal

Accuraspray Usage

- Accuraspray limitations
  - Can be difficult to monitor while actual part is spraying
  - Not tied in for monitoring turntable and manipulation parameters
  - Cannot record gas or flow parameters
  - Difficult to detect long term interruptions in spraying or abnormal events
- Quality control tool not full process monitoring

Who is Using this Technology?

- Most of the major OEMS like GE, PW, Siemens, MHI, Toyota, Volvo Aero, etc…
- Several spray shops such as BASF, FW Gartner, Hitemco, Advanced Coating, etc…
- HVOF on Landing Gear
  - Must have a plume sensor or you can't play in my sandbox
- Honeywell recently had a demonstration

How to Implement Plume Sensor Usage?

- Not on every coating
  - If it ain't broke, don't…….
- Choose problem areas
  - T-800 in booth #2 fails 25% of the time
- Troubleshooting
  - I lost my recipe and I cannot find it……

Accuraspray Usage

- In *production*, Accuraspray can be used to
  - With plume intensity and location can
    - Observe nozzle wear
    - Electrode wear
    - Plume shift
    - Variation in plume intensity indicating possible powder flow issues
      - Hopper issues
      - Carrier gas flow issues
      - Clogging
      - Powder lot changes

Accuraspray Usage

- In purchase of new equipment and movement of equipment
  - Use Accuraspray history for plume, velocity, temperature profiles as a starting point that can be used to transfer settings to any booth or system
  - *Will eliminate days of evaluation and lab testing*

Effect of Hardware-HVOF

	Intensity	Velocity	Temperature	Comments
1	30	635	1795	Bad hardware
2	31	635	1840	Brand new hardware-gas flows changed and equilabrated when new hardware inserted
3	34	638	1900	**Same parameter settings as #1 but look at difference in readings with new hardware**

HVOF Parameter Affects

	Intensity	Velocity	Temperature	Comments
1	80	720	1820	Initial settings
2	103	700	1840	Decrease air and velocity goes down but intensity goes up-stays in flame longer
3	117	743	1875	Raise hydrogen flow which causes ***temperature and velocity*** to rise with an increase in ***intensity*** due to temperature increase-*also both width and height of plume changes*
4	71	700	1780	Decrease oxygen and all values decrease

Accuraspray Usage-HVOF

HVOF WCCoCr Type Powders

	Intensity	Velocity	Temp	Comments
Monday				
Booth DJ#3				
Powder A				
Normal Settings	70	728	2000	Comments11" Stand-off
Powder B				
Normal	36	587	1811	
THEN				
Feedrate 55	43	582	1823	
Air 32	40	563	1830	
Change to Hy 70 Ox 30 Air 32	40	585	1873	***Intensity issues more related to temp than feedrate***
Change to Hy 70 Ox 30 Air 35	50	69	1855	
Also change federate to 55	47	580	1870	
Back to normal with federate of 55 and carrier gas of 32	41	584	1810	
				Could not achieve same results with Powder B

Case Study: "Lot to Lot" Variations (plasma powder)

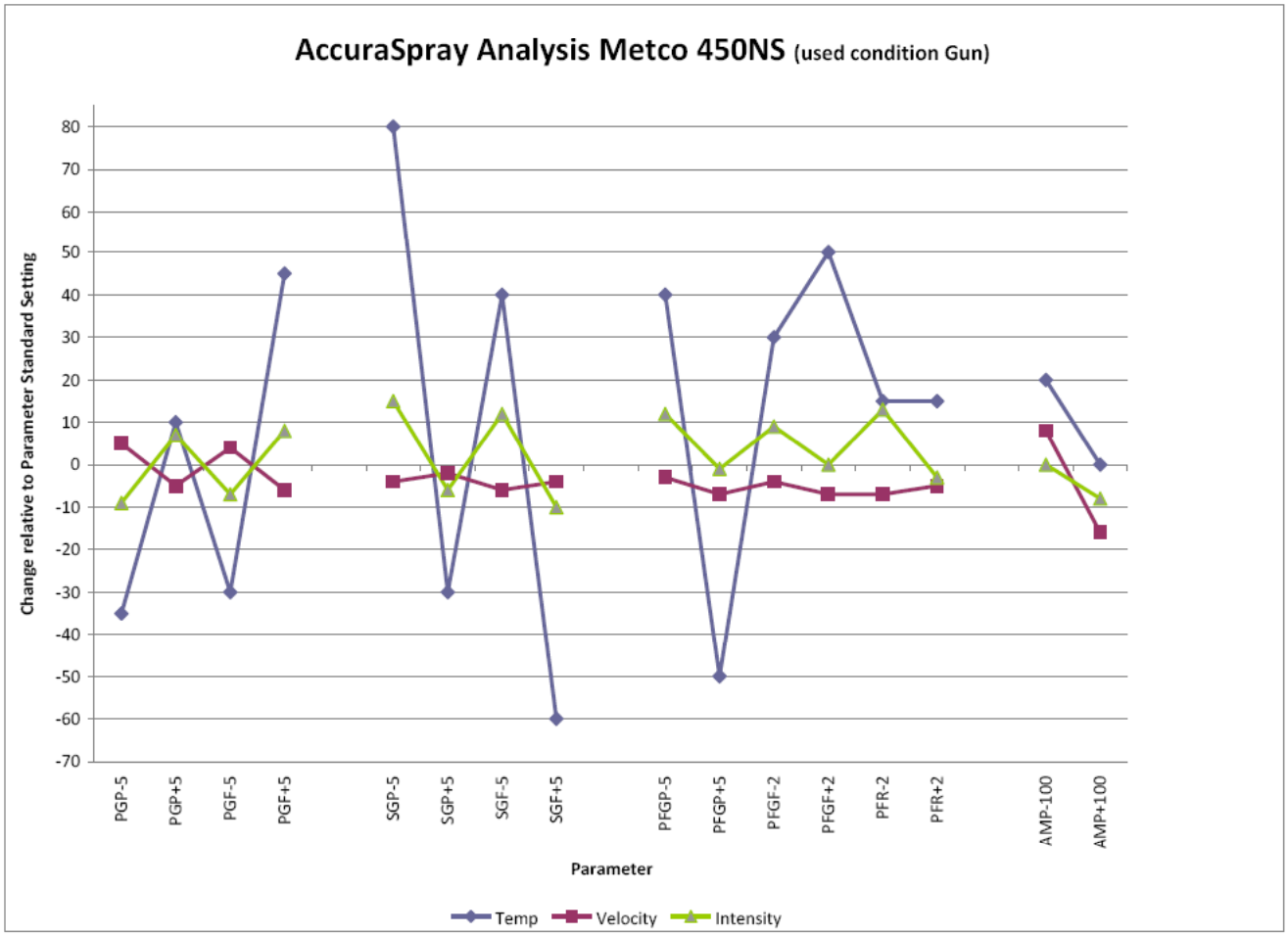
- Two lots of the same plasma powder, sprayed the same morning, in the same booth, by the same operator
- An attempt (successful) was made to retrieve same plume conditions with powder lot B

	T (Celsius)	V (m/s)	Intensity (a.u.)
Lot A	2400	80	95.0
Lot B	2700	84	116.0
Lot B: drop plasma current from 500 to 400 Amps	2400	76	90.0

Map the Current Process

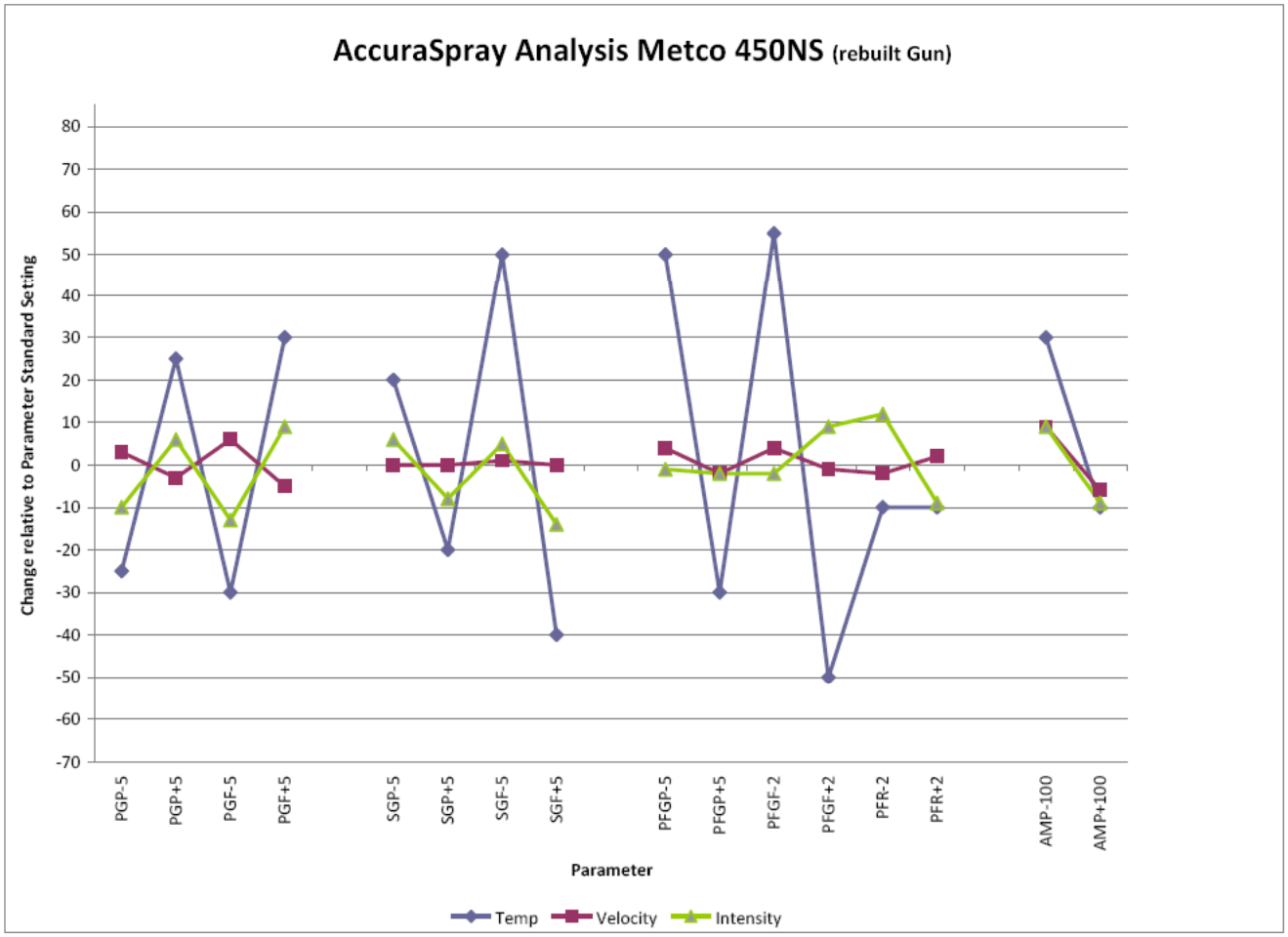
- How do you understand the current process and map what is actually happening in a frozen process?

Plasma Metco 450 *Used* Hardware



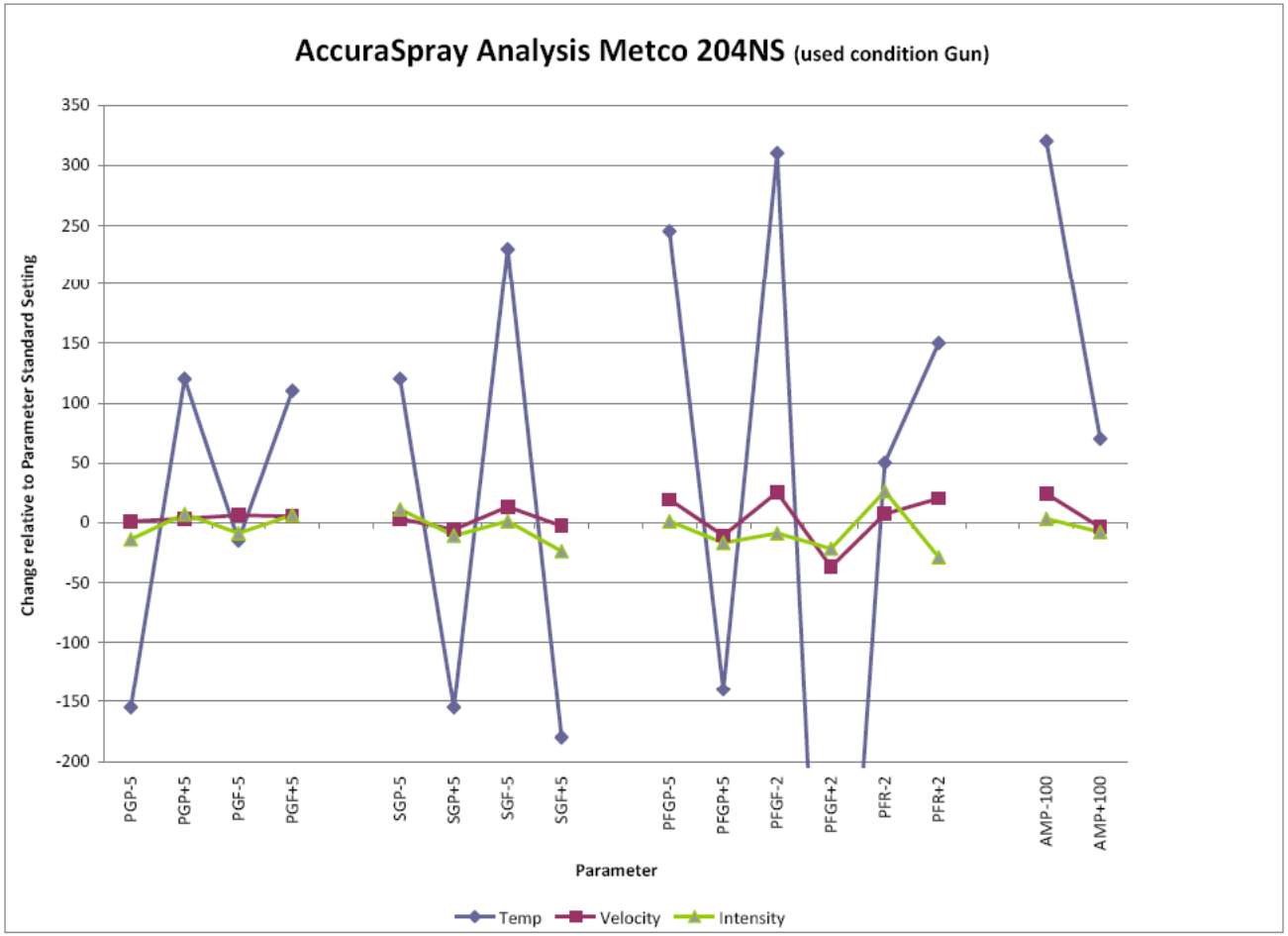
Significant variation

Plasma Metco 450 *New* Hardware



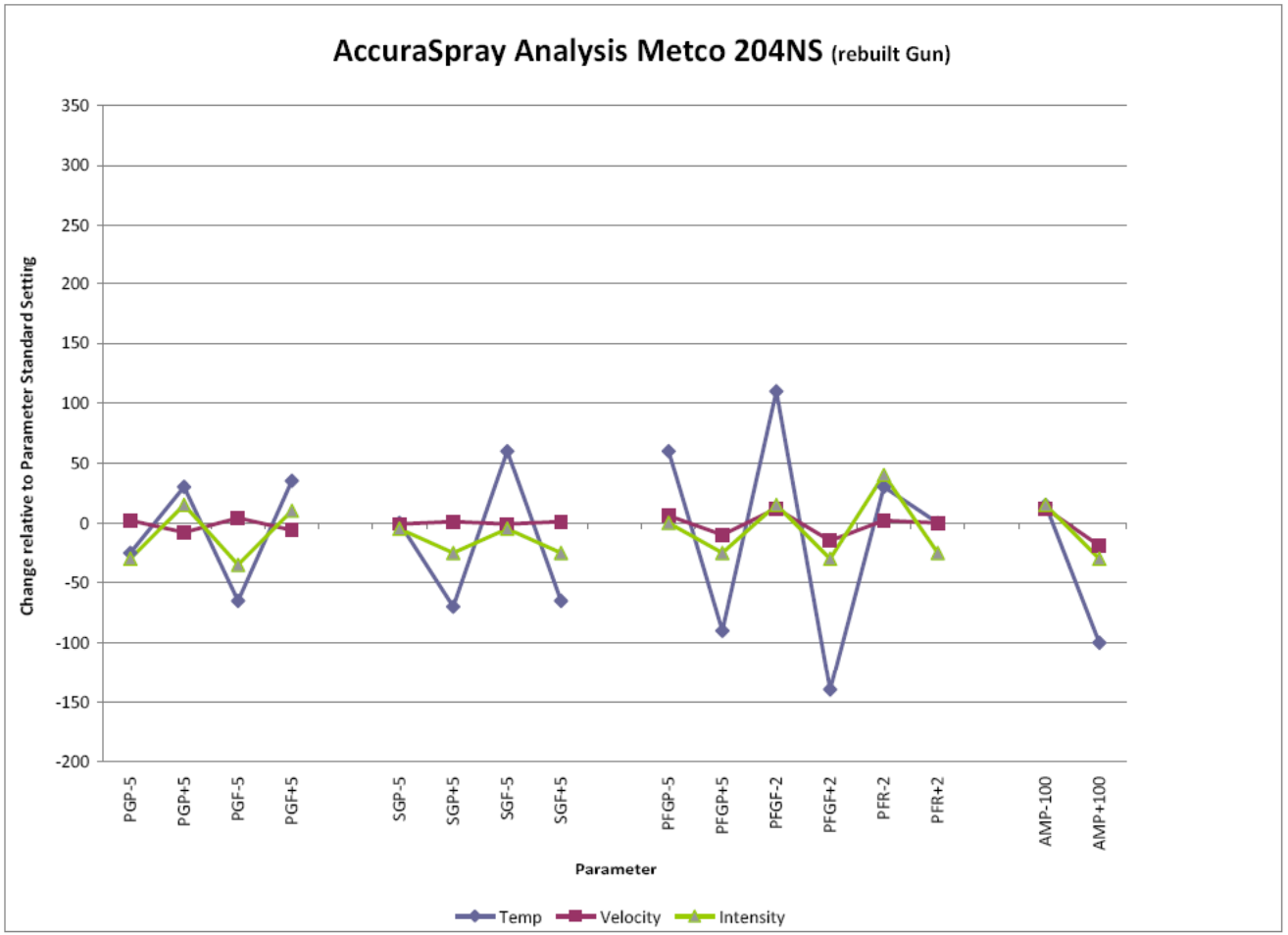
Significant reduction in variation with new hardware

Metco 204NS *Used* Hardware



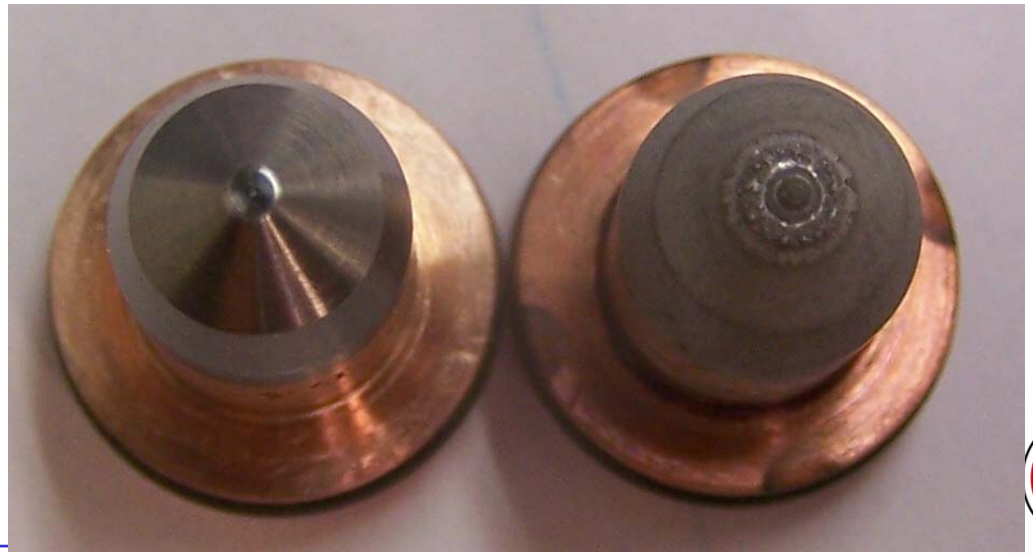
Substantial variation

Metco 204NS *New* Hardware



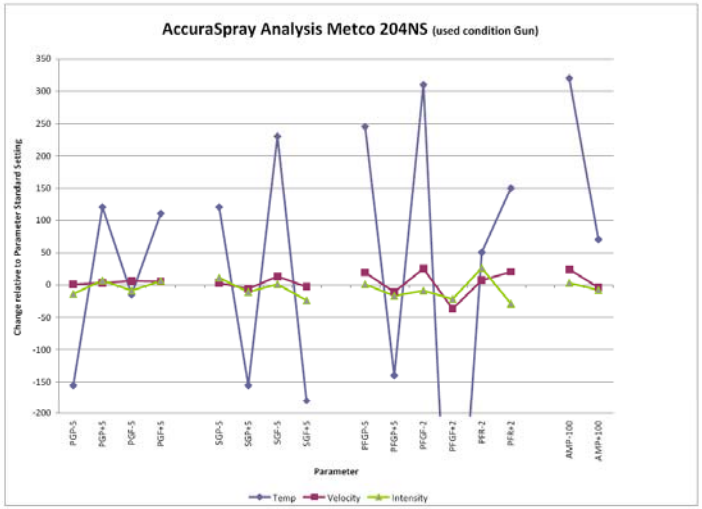
Substantial reduction in variation with new hardware

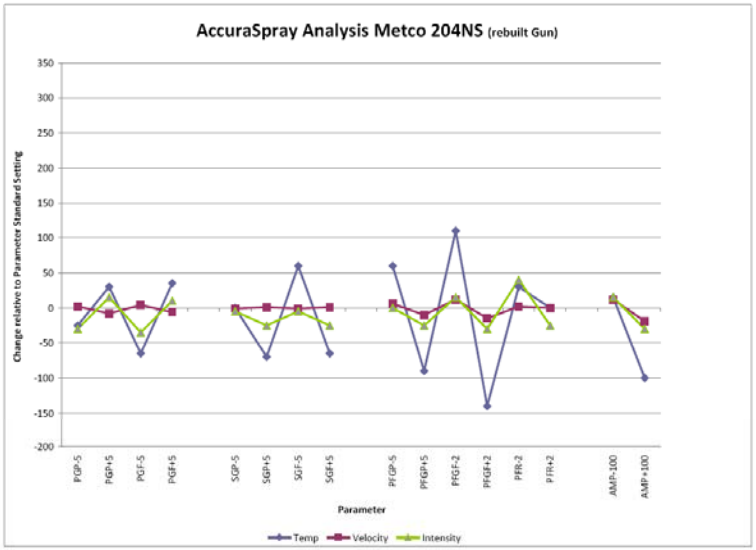
Electrode Wear



Nozzle Wear

Metco 204 Comparison





Understand when hardware is worn out!!

Can We Use It to Replace Testing?

- Never a 100% replacement because the plume sensor does not monitor every ASPECT of the TS process (for instance, it does not take into account surface preparation)
- Can significantly reduce amount and types of testing required

How to Develop Acceptance Limits?

- Correlation of test data with plume sensor info over long term usage with varying gun hardware and powder lots etc.
- “Forced limits” by purposely changing the above referenced parameters and observing where the microstructure, hardness, tensile, etc. drop off

Conclusions

- Plume Sensor Technology is ready for production usage
- Can significantly reduce the amount of aerospace testing required
- Must strategically implement into production to achieve best “bang” for the buck in both time and financial investment
- *Accuraspray demonstrations available upon request*